American Community Survey and Puerto Rico Community Survey Design and Methodology
(Version 3.0)
November 28, 2022

Chapter 11: Weighting and Estimation

U.S. Department of Commerce
U.S. CENSUS BUREAU
census.gov

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Chapter 11: Weighting and Estimation

11.1 Overview

In general, the Census Bureau produces and publishes estimates for the same set of statistical, legal, and administrative entities as the previously published Census long form: the nation, states, American Indian and Alaska Native (AIAN) areas, counties (*municipios* in Puerto Rico), minor civil divisions (MCDs), incorporated places, and census tracts, among others (see Chapter 14, "Data Dissemination"). The Census Bureau publishes up to three sets of estimates for a geographic area depending on its total population.

- For all statistical, legal, and administrative entities, including census tracts, block groups, and small incorporated places, such as cities and towns, the Census Bureau publishes 5-year estimates based on data collected during the 60 months of the five most recent calendar years.
- For geographic entities with populations of at least 20,000, the Census Bureau will also publish 1-year supplemental estimates based on data collected during the 12 months of the most recent calendar year. These tables are generally less detailed and more robust than the standard 1-year tables.
- For geographic entities with populations of at least 65,000, the Census Bureau also publishes single-year estimates based on data collected during the 12 months of the most recent calendar year.

The basic estimation approach is a ratio estimation procedure that results in the assignment of two sets of weights: a weight to each sample person record, both household and group quarters (GQ) persons, and a weight to each sample housing unit (HU) record. As with most household surveys, weights are used to bring the characteristics of the sample more into agreement with those of the full population by compensating for differences in sampling rates across areas, differences between the full sample and the interviewed sample, and differences between the sample and independent estimates of basic demographic characteristics (Alexander, Dahl, & Weidman, 1997).

In particular, the ACS uses ratio estimation to take advantage of independent population estimates by sex, age, race, and Hispanic origin, and estimates of total HUs produced by the Population Estimates Program (PEP) of the Census Bureau. This results in an increase in the precision of the estimates and corrects for under- or over-coverage by geography and demographic detail. This method also produces ACS estimates consistent with the population estimates by these characteristics and the estimates of total HUs for each county in the United States.

For any given geographic area, a characteristic total is estimated by summing the weights assigned to the people, households, families, or HUs possessing the characteristic. Estimates of population characteristics are based on the person weight. Estimates of family, household, and HU characteristics are based on the HU weight.

This chapter describes the weighting methodology used for the 2019 data year, although much of the methodology has been unchanged for many years. Sections 11.2–11.6 describe the single-year weighting and estimation methodology for calculating person weights for the GQ person records as implemented for the 2011 ACS forward. This weighting for GQ persons is done independently of the weighting for HUs. Sections 11.7–11.10 describe the single-year weighting methodology for calculating HU weights and person weights for the household sample records for the 2017 ACS forward. The weighting for household persons makes use of the GQ person weights so that the household and GQ person weights can be combined to produce estimates of the total population. While the methodology for the multiyear weighting is largely the same as the single-year weighting methodology, Section 11.11 outlines where the 5-year weighting methodology differs from the single-year methodology.

11.2 ACS GQ Person Weighting—Overview

Since the 2006 data collection year, estimates from the ACS have included data from both people living in HUs and GQs. The weighting and estimation methodology for GQs significantly changed for the 2011 data year going forward. Readers who are interested in the methodology used prior to 2011 should reference the 12/2010 revision of this chapter posted on the ACS web site. The new methodology was designed to address a significant limitation of the current sample design and the previous weighting methodology. Due to constraints on both sample size and budget, the sample design was optimized at the state level rather than the small area level as is the case for the HU sample. In addition, the lack of independent GQ population estimates at the substate level led to the decision to optimize the weighting at the state level as well to support the GQ products that are released at that level. The trade-off, however, was increased substate variation in both the estimate of total GQ population and the characteristics of that population.

As a result of this variation, there were many counties and tracts that did not have GQ representation even with the five-year estimates (Asiala, Beaghen, & Navarro, 2011). This variation was substantial enough to impact the estimates of the characteristics of the total resident population for the substate areas, including counties (Beaghen & Stern, 2009).

To address this limitation, a new GQ estimation methodology was developed and implemented with the 2011 data products. At its core is a mass imputation procedure whereby whole person records taken from the interviewed sample are copied (i.e., imputed) into not-in-sample GQs. By doing so, the GQ estimates better reflect the substate distribution of the GQs present on the sampling frame and reduce the variability in the substate estimates.

This estimation methodology has four basic components:

- Construct enhanced GQ imputation frame
- Select donors for whole person record imputation into select not-in-sample GQs
- Weighting
- Construct the post-imputation microdata

Each component is described in detail in the subsequent sections.

11.3 ACS GQ Person Weighting—Construct Imputation Frame

The goal of the enhanced GQ imputation frame is to start with the sampling frame for the given year (see Chapter 3 for more details) and update that frame with all information regarding the frame that is collected during the year. Most updates that are available come from sample cases that were fielded after the creation of the sampling frame. These updates include the number of persons residing in the GQ, GQ type, and identification of nonexistent or out-of-scope GQ facilities.

If only the size of the sampled facilities were updated on the enhanced frame, then the imputation into the not-in-sample facilities would not reflect the trends observed in the in-sample facilities. For example, if GQs that were in sample for a particular major type are tending to be larger than expected the same trend is expected to occur in the not-in-sample GQs for the same major type.

For this reason, the expected populations of the not-in-sample GQs are adjusted using the empirical relationship between the observed and expected population for the in-sample GQs. This adjustment is calculated within cells defined by major GQ type (see Table 11-1) by size class (small GQ, large GQ but not in sample with certainty, large GQ in sample with certainty). Note that, in addition to the standard seven major GQ types used for sampling and weighting, Federal Prisons are separated from other Correctional Institutions for the imputation because of differences in data sources and data collection methods. In the final weighting methodology, only the seven standard major types are used.

Table 11-1. Major GQ Type

Major GQ type	Definition	Institutional/Noninstitutional
0	Correctional Institutions—Federal Prisons	Institutional
1	Correctional institutions—Other	Institutional
2	Juvenile Detention facilities	Institutional
3	Nursing homes	Institutional
4	Other Long-Term Care facilities	Institutional
5	College Dormitories	Noninstitutional
6	Military facilities	Noninstitutional
7	Other Noninstitutional facilities	Noninstitutional

To improve the imputation, a flag is set on the enhanced frame to identify single-sex facilities. A facility is designated as a single sex facility using either the Federal Bureau of Prisons demographics file, historical ACS sample interview data, or the most recent census for facilities with no historical ACS sample interview data. If the sex distribution for the GQ is at least 90% male or 90% female, then it is identified as a single-sex GQ and only persons of that sex are imputed into that facility. All other GQs do not take sex into account when imputing records into the facility. For more information on creating the enhanced frame, see the detailed computer specifications (Bullock, 2018a).

11.4 ACS GQ Person Weighting—Select Donors for Imputation

The overarching goal of the imputation procedure is for the substate GQ estimates to better reflect the distribution present on the frame. To accomplish this, this goal is separated into two objectives:

- To establish representation of county by major type in the tabulations for each combination that exists on the frame for the 1- and 5-year data.
- To establish representation of tract by major type in the tabulations for each combination that exists on the frame for the 5-year data.

To accomplish these two objectives, while providing some limits on the degree of imputation required, the imputation is targeted towards two groups:

- All not-in-sample GQs that have an expected population of greater than 15 persons are selected to receive imputed whole person records.
- A subset of the not-in-sample GQs that have an expected population of 15 or fewer persons likewise are selected as necessary to achieve the two objectives stated above.

The larger GQs are selected with certainty to ensure a base distribution of the GQ estimates in the broadest set of geographic areas. Since these GQs contain the largest proportion of the GQ population, targeting these GQs to receive imputed records has the greatest visibility and impact on the estimates. The smaller GQs are selected only as needed to achieve the stated objectives for areas that do not meet those objectives after accounting for the sample GQs and the imputation into the not-in-sample larger GQs. Thus, if there is a tract by major type combination that exists on the enhanced frame that is comprised of entirely small GQs and no interviewed sample exists, then one small GQ is selected at random to represent the set of small GQs that exist for that combination.

Once the GQs are selected for imputation, the number of imputed person records to allocate to each GQ is determined. For the larger GQs, the number of imputed GQ person records is calculated as the larger of 2.5% of the expected population or one. For the smaller GQs, the number of imputed person records is the larger of 20% of the expected population or one.

Once the subset of not-in-sample GQs has been selected and the number of GQ imputed records to be assigned to the GQ has been computed, donors from the interviewed sample are selected. The selection process is implemented through an expanding search algorithm that first searches for a donor within county of the same specific GQ type. The specific types are a more detailed breakdown of the seven major types into more than 30 specific types. For example, the major type for correctional institutions is further classified into federal prisons, state prisons, jails, and half-way houses. If a donor is not found, the search expands to within county but of the same major GQ type. If a donor is still not found, the geographic region is expanded, and the process repeats until a donor is found. The levels of search are as follows:

- Within a geographic level, the search is first within the same specific type and then within the same major type
- Geographic levels expand as necessary in the following order: county, state, division, region, nation

To guard against the excessive reuse of donors, a particular donor is limited to being used three times within a single tract and five times within a single county. For more information on selecting donors, see the detailed computer specifications (Bullock, 2018b).

11.5 ACS GQ Person Weighting—Base Weights, Constraints, and Controls

The GQ weighting makes no distinction between the sampled and imputed GQ person records. The weighting has three basic steps: assigning an initial weight that reflects the observed combined sampled/imputed rate, an adjustment of those weights to match substate totals from the enhanced frame, and a coverage adjustment at the state level.

Base Weights

The base weights (BW) for GQ persons are defined so that the sum of the base weights is equal to the domain that they represent. That domain differs depending on whether the GQ is small or large. Large GQs are self-representing and thus the sum of the base weights for the persons in that GQ is equal to the actual or adjusted expected population of the GQ. The base weights for all persons in the GQ are defined to be equal and hence, for the i-th person in the GQ, BW is defined as follows:

$$BW_i = \text{Actual or adjusted expected population, } N_P \text{, of the GQ} \div \text{Total number of sampled or imputed GQ person records, } n_p$$

$$= \frac{N_p}{n_p}$$

For the small GQs, the domain that the sum of the base weights is to represent is the total GQ population residing in small GQs for the tract by major type combination. Thus, the definition of BW is adjusted to account for the potential random selection of the small GQ with sampled or imputed data from the set of all small GQs in the tract by major type combination:

BW_i = (Number of small GQs, N_{GQ}, on frame for the tract by major type combination
÷
Number of small GQs, n_{gq}, with either sampled or imputed GQ person records)
×
(Actual or adjusted expected population, N_P, of the GQ
÷
Total number of sampled or imputed GQ person records, n_p)

$$= \frac{N_{GQ}}{n_{gq}} \times \frac{N_p}{n_p}$$

Note that, as defined, the base weights also account for nonresponse within the GQ and within the tract (for small GQs).

Tract-level Constraint

The next steps are a series of constraints to ensure that the weighted totals of the sample and imputed records match the frame totals of adjusted population. One reason why the sum of the initial weights may not match the frame totals is the fact that the base weights of the small GQs reflect the equal probability selection of the small GQs within a tract (for the imputed GQs).

While in expectation, the sum of the base weights may match the frame totals at the tract level, there may be a small deviance between the two because the first factor in the base weight calculation does not account for the population totals of the small GQs.

The tract-level constraint is thus defined as follows:

$TRCON_{tg}$ = Sum of adjusted GQ population, *ADJEXPOP*, for all GQs, *j*, on the enhanced frame within the tract t and major type g
÷
Sum of base weights for all GQ person records, *i*, sampled or imputed in tract t and major type g

$$= \frac{\sum_{\mathrm{GQ=j}} ADJEXPOP_j}{\sum_{\mathrm{Person}=i} BW_i}$$

The weight after the tract-level constraint, *WTRCON*, is achieved by multiplying the constraint factor by the base weight:

$$WTRCON_i = BW_i \times TRCON_{t(i)g(i)}$$

County-level Constraint

A second source of deviance between the weighted totals and the frame counts are ungeocoded GQs on the frame. These GQs do not have the census block codes required for tabulation but do have a county code assigned to them. For this reason, ungeocoded GQs are ineligible for imputation (they are still eligible for sampling, however, where they can be geocoded during data collection). To maintain consistency with the frame, the population total of all ungeocoded GQs on the frame are distributed to the geocoded GQs within county and major type via the county-level constraint. Note that in 2011 when the methodology was developed, the issue of ungeocoded records was relatively small because of the robustness of the sampling frame that was built from the 2010 Census. In future years, new updates to the frame that cannot be geocoded through automated means may make this constraint more important. The county-level constraint is defined as follows:

$CTYCON_{cg}$ = Sum of adjusted GQ population for all GQs, j, on the enhanced frame within the county c and major type g
÷
Sum of the weight after the tract-level constraint for all GQ person records, i, sampled or imputed in county c and major type g

$$= \frac{\sum_{\text{GQ} = j} ADJEXPOP_j}{\sum_{\text{Person} = i} WTRCON_i}$$

The weight after the county-level constraint, *WCTYCON*, is achieved by multiplying the constraint factor by the weight after the tract-level constraint:

$$WCTYCON_i = WTRCON_i \times CTYCON_{c(i)g(i)}$$

State-level Constraint

The last constraint is designed to be a safety net in case there exists an ungeocoded GQ in a county where there are no geocoded GQs of the same major type. In that case, the population of that GQ is spread over all GQs of the same major type within the state. In practice, this is a relatively rare situation and the constraint is very close to one.

The state-level constraint is defined as follows:

$STCON_{sg}$ = Sum of adjusted GQ population for all GQs, j, on the enhanced frame within the state s and major type g
÷
Sum of weight after the county-level constraint for all GQ person records, i, sampled or imputed in state s and major type g

$$= \frac{\sum_{\text{GQ} = j} ADJEXPOP_j}{\sum_{\text{Person} = i} WCTYCON_i}$$

The weight after the state-level constraint, *WSTCON*, is achieved by multiplying the constraint factor by the weight after the county-level constraint:

$$WSTCON_i = WCTYCON_i \times STCON_{s(i)g(i)}$$

GQ Post-Stratification Adjustment to Controls

The final step in the GQ person weighting process is to apply the GQ Person Post-Stratification Factor (*GQPPSF*). The post-stratification cells are defined within state by GQ major type. This is consistent with the nature of the PEP GQ population estimates that are updated and maintained by major type. Using state as the level of geography for the post-stratification allows the GQ distribution on the frame to drive the substate distribution of the estimates.

All sample interviewed and imputed persons are placed in their appropriate cells. The *GQPPSF* for each cell is then calculated:

$GQPPSF_{sg}$ = PEP GQ population estimate for state s and major type g
÷
Sum of weight after the state-level constraint for GQ person records that are either interviewed sample or imputed in state s and major type g

$$= \frac{GQPOP_{sg}}{\sum_{\text{Person} = i} WSTCON_i}$$

where

$GQPOP_{sg}$ = PEP GQ population estimate for state s and major type g.

The weight after post-stratification, *WGQPPSF*, is achieved by multiplying the post-stratification factor by the weight after the GQ state constraint adjustment:

$$WGQPPSF_i = WSTCON_i \times GQPPSF_{s(i)g(i)}$$

These weights are then rounded to form the final GQ person weights. For more information on creating the GQ person weights, see the detailed computer specifications (Jordan, 2018a).

11.6 ACS GQ Person Weighting—Post-Imputation Microdata

The final person-level microdata are assembled by concatenating the sample interview microdata with the imputed records. The microdata for each imputed record is created by joining the geographic information of the GQ selected for imputation with the edited response information from the donor. For geographically-tied characteristics, some adjustments are necessary in order to preserve certain data relationships. For example, if the donor listed the same county for their residence one year ago as their current county of residence, the microdata for the imputed record is adjusted so that the same relationship is true for the donee record as was true for the donor record. Similar procedures are performed to preserve analogous relationships for place of work and journey to work. These steps help maintain the integrity of these characteristics for the imputed person records so that the estimates formed from the sampled and imputed records are not adversely impacted. For more information on creating the post-imputation microdata, see the detailed computer specifications (Jordan, 2018b).

11.7 ACS HU Weighting—Overview

The single-year weighting is implemented in three stages. In the first stage, weights are computed to account for differential selection probabilities based on the sampling rates used to select the HU sample. In the second stage, weights of responding HUs are adjusted to account for nonresponding HUs. In the third stage, weights are controlled so that the weighted estimates of HUs and persons by age, sex, race, and Hispanic origin conform to estimates from the PEP of the Census Bureau at a specific point in time. The estimation methodology is implemented by "weighting area," either a county or a group of less populous counties. Note that this section reflects the methodology as implemented after the telephone mode of data collection was discontinued. Readers who are interested in the methodology used prior to 2017 should reference the 01/2014 revision of this chapter posted on the ACS web site.

11.8 ACS HU Weighting—Probability of Selection

The first stage of weighting involves two steps. In the first step, each HU is assigned a basic sampling weight that accounts for the sampling probabilities in both the first and second phases of sample selection. Chapter 4 provides more details on the sampling. In the second step, these sampling weights are adjusted to reduce variability in the monthly weighted totals.

Sampling Weight

The first step is to compute the basic sampling weight for the HU based on the inverse of the probability of selection. This sampling weight is computed as a multiplication of the base weight (*BW*) and a Computer-Assisted Personal Interviewing (CAPI) subsampling factor (*SSF*). The *BW* for an HU is calculated as the inverse of the final overall first-phase sampling rate which, for 2017, ranges from approximately 0.5 percent to 15 percent. HUs sent to CAPI are eligible to be subsampled (second-phase sampling) at rates generally ranging from 1-in-3 to 2-in-3 except for areas in remote Alaska and select American Indian areas which have a 100 percent CAPI sampling rate (see Chapter 4 for further details). Those selected for the CAPI subsample, and for which no late mail or internet return is received in the CAPI month, are assigned a CAPI *SSF* equal to the inverse of their (second-phase) subsampling rate. Those not selected for the CAPI subsample receive a factor of 0.0. HUs for which a completed mail or internet return is received, regardless of if it was eligible for CAPI, receive a CAPI *SSF* of 1.0. The CAPI *SSF* is then used to calculate a new weight for every HU, the weight after the CAPI subsampling factor (*WSSF*). It is equal to the *BW* times the *SSF*. After each of the subsequent weighting steps, a new weight is calculated as the product of the new factor and the weight following the previous step.
Table 11-2 summarizes the computation of the *WSSF* by weighting step and the sample disposition of HUs. Additional information can be found in the detailed computer specifications for the HU weighting (Albright, 2018).

Table 11-2. Computation of the Weight after CAPI Subsampling Factor (*WSSF*)

Weighting step	Sample Disposition for mail/internet respondent	Sample Disposition for CAPI sampled units	Sample Disposition for CAPI non-sampled units	Sample Disposition for CAPI eligible, but ultimately mail/internet respondent
Base Weight (*BW*)	1 ÷ OSR	1 ÷ OSR	1 ÷ OSR	1 ÷ OSR
CAPI Subsampling Factor (*SSF*)	1	1 ÷ SSR	0	1
Weight after Subsampling Factor (*WSSF*)	1 ÷ OSR	(1 ÷ OSR) × (1 ÷ SSR)	0	1 ÷ OSR

Notes: OSR = Original Sampling Rate for sample record
SSR = CAPI Subsampling Rate for sample record

Variation in the Monthly Sample Factor

The goal of ACS estimation is to represent the characteristics of a geographic area across the specified period. For single-year estimates, this period is 12 months, and for 5-year estimates, it is 60 months. The annual sample is allocated into 12 monthly samples. The monthly sample becomes a basis for the operations of the ACS data collection, preparation, and processing, including weighting and estimation.

The data for HUs assigned to any sample month can be collected at any time during a 3-month period. For example, the households in the January sample month can have their data collected in January, February, or March. Each HU in a sample belongs to a tabulation month (the month the interview is completed). This is either the month the processing center checked in the completed mail questionnaire, the month internet questionnaire is submitted, or the month the interview is completed by CAPI.

Because of seasonal variations in response patterns, the number of HUs in tabulation months may vary, thereby over-representing some months and under-representing other months in the single- and multiyear estimates. For the ACS to represent equitably the time period across the entire year, an even distribution of HU weights by month is desirable. To smooth out the total weight for all sample months, a variation in monthly response factor (*VMS*) is calculated for each month, m, as:

VMS_m = Total base weights of all HUs in that sample month
÷
Total weight after CAPI subsampling adjustment factor of all HUs interviewed in that sample month

$$= \frac{\sum_{i \epsilon \text{Sample Month(m)}} BW_i}{\sum_{i \epsilon \text{Interview Month(m)}} WSSF_i}$$

where

BW_i = base weight for sample HU *i*,

$WSSF_i$ = weight after the CAPI subsampling factor for interviewed HU *i*.

This adjustment factor is computed within each of the 2,175 ACS single-year weighting areas (either a county or a group of less populous counties). The index for weighting area is suppressed in this and all other formulas for weighting adjustment factors.

Table 11-3a and Table 11-3b illustrate the computation of the *VMS* adjustment factor within a particular county for the numerator and denominator respectively. In this example, the total *BW* for each sample month is 100 (as shown in Table 11-3a). The total *WSSF* weight across modes within each month varies from 90 to 115 (as shown in the first line of Table 11-3b). The *VMS* factors are then computed by month as the ratio of the total *BW* to the total *WSSF* (as shown in the final line of Table 11-3b).

Table 11-3a. Example of Computation of Variation in Monthly Response Factor (VMS)—Numerator: Sum of Base Weight Across Sample Month

Numerator	March	April	May	June	July
Total base weight (*BW*) across released samples	100	100	100	100	100

Table 11-3b. Example of Computation of Variation in Monthly Response Factor (VMS)—Denominator: Sum of Weight After CAPI Subsampling Across Interview Month

Denominator and Components	March	April	May	June	July
Denominator: Total Weight after CAPI Subsampling (*WSSF*) across modes	115	95	90	100	105
Total weight of mail returns from three panels	55 Jan-Mar sample	45 Feb-Apr sample	40 Mar-May sample	45 Apr-Jun sample	50 May-Jul sample
Total weight of internet returns from three panels	30 Jan-Mar sample	25 Feb-Apr sample	30 Mar-May sample	30 Apr-Jun sample	25 May-Jul sample
Total weight of CAPI sample	30 Jan sample	25 Feb sample	20 Mar sample	25 Apr sample	30 May sample
VMS Adjustment Factor (numerator from 11-3a divided by denominator above)	100 ÷ 115	100 ÷ 95	100 ÷ 90	100 ÷ 100	100 ÷ 105

The weight after the variation of monthly response adjustment (*WVMS*) is the product of the weight after CAPI subsampling factor (*WSSF*) and the variation of monthly response factor (*VMS*). When the *VMS* factor is applied, the total weight across all HUs tabulated in a sample month is equal to the total base weight of all HUs selected in that month's sample. The result is that each month contributes approximately 1/12 to the total single-year estimates. In other words, the single-year estimates of ACS characteristics are a 12-month average without over- or under-representing any single month due to variation in monthly response.

11.9 ACS HU Weighting—Noninterview Adjustment

The noninterview adjustment changed for the 2017 data year moving forward. Readers who are interested in the methodology used prior to 2017 should reference the 01/2014 revision of this chapter posted on the ACS web site. The new methodology simplifies the adjustments done in prior years, without impacting data quality (Gutentag, Asiala, & Castro, 2018).

During data collection, nothing new is learned about the HU or person characteristics of noninterviewed HUs, so only characteristics known at the time of sampling can be used in adjusting for them. In other surveys and censuses, characteristics that have been shown to be related to HU response include census tract and building type grouped into single- versus multi-unit structure (Weidman, Alexander, Diffendal, & Love, 1995). It is expected that many other characteristics may be correlated with these characteristics given the local nature of the adjustment. The noninterview adjustment step is applied to all HUs interviewed by any mode—mail, internet, or CAPI.

Note that vacant units and ineligible units such as deletes are excluded from the noninterview adjustment.[1]The weight corresponding to these HUs remains unchanged during this stage of the weighting process since it is assumed that all vacant units and deletes are properly identified in the field and therefore are not eligible for the noninterview adjustment. The weighting adjustment is carried out only for the occupied, temporarily occupied (those HUs which are occupied but whose occupants do not meet the ACS residency criteria), and noninterviewed HUs. After completion of the adjustment to the weights of the interviewed HUs, the noninterviewed HUs can be dropped from subsequent weighting steps; their assigned weights are equal to 0.

Calculation of the Noninterview Adjustment Factor

In this step, all HUs are placed into adjustment cells based on the cross-classification of building type (single- versus multi-unit structures) and census tract. If a cell contains fewer than 10 interviewed HUs, it is collapsed with an adjoining tract until the collapsed cell meets the minimum size of 10.[2] Cells with zero noninterviews are not collapsed, regardless of size, unless

[1] Deletes or out-of-scope addresses fall into three categories: (1) addresses of living quarters that have been demolished, condemned, or are uninhabitable because they are open to the elements; (2) addresses that do not exist; and (3) addresses that identify commercial establishments, units being used permanently for storage, or living arrangements known as group quarters.

[2] Data are sorted by the weighting area, building type, and tract. Within a building type, a tract that has 10 or more responses is put in its own tract. A tract that has no nonresponses and some responses (even though the total is fewer than 10) is put in its own tract. A tract that has nonresponses and fewer than 10 responses is collapsed with the next tract. If the final tract needs to be collapsed, it is collapsed with the previous tract.

they are forced to collapse with a neighboring cell that fails the size criterion. The noninterview adjustment factor (*NIF*) for each eligible cell, c, is:

NIF_c = Total HU weight in cell c after variation in monthly response adjustment factor of interviewed occupied and temporarily occupied HUs and noninterviewed HUs
÷
Total HU weight after variation in monthly response adjustment factor of interviewed occupied and temporarily occupied HUs

$$= \frac{\sum_{i\epsilon \text{Interviews(c)}} WVMS_i + \sum_{i\epsilon \text{Noninterviews(c)}} WVMS_i}{\sum_{i\epsilon \text{Interviews(c)}} WVMS_i}$$

where

$WVMS_i$ = Adjusted HU weight after the variation in monthly response adjustment for HU i

All occupied and temporarily occupied interviewed HUs are adjusted by this noninterview factor. Vacant and deleted HUs are assigned a factor of 1.0, and noninterviews are assigned a factor of 0.0. The computation of the weight after the noninterview adjustment factor is summarized in Table 11-4 below.

Table 11-4. Computation of the Weight after the Noninterview Adjustment (*WNIF*)

Interview status	$WNIF_i$
Occupied or temporarily occupied HU	$WVMS_i \times NIF_{c(i)}$
Vacant or deleted HU	$WVMS_i$
Noninterviewed HU	0

11.10 ACS HU Weighting—Housing Unit and Population Controls

This stage of weighting forces the ACS total HU and person weights to conform to estimates from the Census Bureau PEP. The PEP of the Census Bureau annually produces estimates of population by sex, age, race, and Hispanic origin, and total HUs for each county in the United States as of July 1. They also produce annually updated estimates of total population for incorporated places and minor civil divisions (MCDs) as of July 1. The ACS estimates are based on a probability sample and may vary from their true population values due to sampling and nonsampling error (see Chapters 12 and 14). In addition, it can be seen from the formulas for the adjustment factors in the previous two sections that the ACS estimates also vary based on the combination of interviewed and noninterviewed HUs in each tabulation month. As part of the process of calculating person weights for the ACS, estimates of totals by sex, age, race, and Hispanic origin are controlled to be equal to population estimates by weighting area. There are two reasons for this: (1) to reduce the variability of the ACS HU and person estimates, and (2) to reduce bias due to under-coverage of HUs and the people within them in household surveys. The bias that results from missing these HUs and people is partially corrected by using these controls (Alexander, Dahl, & Weidman, 1997).

The assignment of final weights involves the calculation of three factors based on the HU and population controls. The first adjustment involves the independent HU estimates. A second and separate adjustment relies on the independent population estimates. The final adjustment is implemented to achieve consistency between the ACS estimates of occupied HUs and householders.

Models for PEP Estimates of HUs and Population

The Census Bureau produces estimates of total HUs for states and counties as of July 1 on an annual basis. The estimates are computed based on a model:

$$\mathrm{HU1X} = \mathrm{HU10} + (\mathrm{NC1X} + \mathrm{NM1X}) - \mathrm{HL1X}$$

where the suffix “X” indicates the year of the housing unit estimates, and HU1X = Estimated 201X HUs

HU10	=	Geographically updated 2010 Census HUs
NC1X	=	Estimated new residential construction, April 1, 2010 to July 1, 201X
NM1X	=	Estimated new residential mobile home placements, April 1, 2010 to July 1, 201X
HL1X	=	Estimated residential housing loss, April 1, 2010 to July 1, 201X.

More detailed background on the current methodology used for the HU estimates can be found on the Census Bureau’s website (U.S. Census Bureau, 2020a).

The Census Bureau also produces population estimates as of July 1 on an annual basis. Those estimates are computed based on the following simplified model:

$$\mathrm{P1} = \mathrm{P0} + \mathrm{B} - \mathrm{D} + \mathrm{NDM} + \mathrm{NIM} + \mathrm{NMM}$$

where

P1	=	population at the end of the period (current estimate year)
P0	=	population at the beginning of the period (previous estimate year)
B	=	births during the period
D	=	deaths during the period
NDM	=	net domestic migration during the period
NIM	=	net international migration during the period
NMM	=	net military movement during the period

In practice, the model is considerably more complex to leverage the best information available from multiple sources. More detailed background on the current methodology used for the HU estimates can be found on the Census Bureau’s website (U.S. Census Bureau, 2020b).

Production of the population estimates for Puerto Rico is limited to population totals by *municipio,* and by sex-age distribution at the island level. For this reason, estimates of totals by *municipio*, sex, and age for the PRCS are controlled to be equal to the population estimates. Currently, there are no HU estimates available from the PEP for Puerto Rico.

Creation of the Subcounty Control Areas

The subcounty control areas are formed to give both MCDs and incorporated places the benefit of using subcounty controls. To achieve this balance, the basic units for forming the subcounty areas are the county/MCD/place intersections or parts where the "balance of county" is also considered as another fundamental subcounty area. Note that outside of the strong and weak MCD states (U.S. Census Bureau, 2020c) for which the PEP produce total population estimates this defaults to simply the county/place parts. These subcounty areas are then combined until all subcounty areas within a county have a total population of 24,000 or greater. If it is not possible to partition a county into two or more subcounty areas of this size, then the subcounty area is simply coexistent with the county.

Calculation of Housing Unit Post-Stratification Factor

Note that both HU and population estimates used as controls have a reference date of July 1 which means that the 12-month average of ACS characteristics is controlled to the population with the reference date of July 1. If person weights are controlled to the population estimates as of that date, it is logical that HUs also are controlled to those estimates to achieve a consistent relationship between the two totals.

The housing unit post-stratification factor (*HPF*) is employed to adjust the estimated number of ACS HUs by subcounty area within a weighting area to agree with the PEP estimates. For the subcounty area, *sa*, within a weighting area, this factor is:

HPF_{sa} = PEP HU estimate for the subcounty area, *sa*

÷

Total HU weight after the non-interview adjustment across all interviewed occupied, interviewed temporarily occupied, and vacant HUs i for the subcounty area, *sa*,

$$= \frac{HU_{sa}}{\sum_{i \epsilon \text{Occupied and Vacant Interviews (sa)}} WNIF_i}$$

Note that if the PEP HU subcounty estimates are summed across all subcounty areas within a county, the total is consistent with the PEP county-level HU estimates. The denominator of the *HPF* formula aggregates the adjusted HU weight after the noninterview factor adjustment (*WNIF*) across 12 months for the interviewed occupied, temporarily occupied, and vacant HUs. All HUs then are adjusted by this HU post-stratification factor. Therefore, *WHPF* = *WNIF* × *HPF*, where *WHPF* is the adjusted HU weight after the HU post-stratification factor adjustment.

Calculation of Person Weights

The next step in the weighting process is to assign weights to persons via a three-dimensional raking-ratio estimation procedure. This is done so that (1) the estimate of total population for the subcounty areas conform to the population estimates; (2) the combined estimates of spouses and unmarried partners conform to the combined estimate of married-couple and unmarried-partner households and the estimate of householders conforms to the estimate of occupied HUs; and (3) the estimates for certain demographic groups are equal to their population estimates.

The population estimates used for the household person weighting are derived from the PEP estimates of total resident population by first starting with the PEP total and then subtracting the corresponding ACS GQ estimate for that same population. For example, the control total used for county household population is derived by subtracting the ACS GQ estimate of total GQ population from the PEP estimate of total resident population. By doing so, the ACS estimate of total resident population (formed by summing the household and GQ population) conforms to the PEP estimate for the same population. This procedure is also used to derive the controls for subcounty areas and demographics as well.

Each person in an interviewed occupied HU is assigned an initial person weight equal to the HU weight after the HU post-stratification factor is applied (*WHPF*). Next there are three steps of ratio adjustment. The first step uses one cell per subcounty control area defined within the weighting area. The second step uses four cells to classify persons by spousal relationship, householder, and non-householder. The third step uses up to 156 cells defined by race/Hispanic origin, sex, and age. The steps are defined as follows:

Step 1: Subcounty Population Controls. All persons are assigned to one subcounty area within the weighting area. The marginal totals (i.e., the single-dimension control totals for a raking matrix) are simply equal to the derived household population control totals for the subcounty area as described above.

Step 2: Spouse / Unmarried Partner and Householders. All persons are placed into one of four cells:

1. Persons who are the primary person in a two-partner relationship—all householders in a married-couple or unmarried-partner household,
2. Persons who are the secondary person in a two-partner relationship—all spouses or unmarried partners in those same households, or
3. Persons who are a householder but do not fit into the first cell, or
4. Balance of population—all persons not fitting into the first three cells.

The marginals for the first two columns of cells are both equal to the estimate of married-couple plus unmarried-partner households using the *WHPF* weight. The marginal for the third column is the estimate of occupied HUs using the *WHPF* weight minus the marginal for the first column.

In this manner, the estimate of households, equal to first column plus the third column of cells, is controlled to the estimate of occupied HUs. The marginal for the fourth column is equal to the derived household population estimate minus the sum of the marginals used for the other three columns of cells. In this manner, the estimate of total household population is controlled to the derived population estimates.

Step 3: Race-Hispanic Origin/Sex/Age. The third step assigns all persons to one of up to 156 cells: six classifications of race-Hispanic origin by sex by 13 age groups. The marginals for these rows at the weighting area level come from the derived population estimates (PEP total resident population minus the ACS GQ estimate for the same characteristic cross-classification). Some weighting areas do not have sufficient sample to support all 156 cells and, in these cases, some collapsing is necessary. This collapsing is done prior to the raking and remains fixed for all iterations of the raking.

Race and Hispanic origin are combined to define six unique race-ethnicity groups consistent with those used in weighting the Census 2000 long form. These groups are created by crossing "Non-Hispanic" with the five major single race groups, plus the group of all Hispanics regardless of race. The race-ethnicity groups are:

1. Non-Hispanic White
2. Non-Hispanic Black
3. Non-Hispanic American Indian and Alaskan Native (AIAN)
4. Non-Hispanic Asian
5. Non-Hispanic Native Hawaiian or Pacific Islander (NHPI)
6. Hispanic

The assignment of a single major race to a person can be complicated because people can identify themselves as being of multiple races. People responding either with multiple races or "Other Race" are included in one of the six race-ethnicity groups for estimation purposes only. This reduces the likelihood of creating many sparse cells which could cause extreme adjustments while grouping race-ethnicity groups of similar coverage rates together. Subsequent ACS tabulations are based on the full set of responses to the race question.

Initial estimates of population totals are obtained from the ACS sample for each of the weighting area/race-ethnicity groups. These estimates are calculated based on the initial person weight of *WHPF*. The demographic control totals are derived from the Census Bureau's PEP total resident population estimate minus the ACS GQ estimate for each weighting area/race-ethnicity group. These derived population estimates are used as control totals in the remaining steps of the ACS household person weighting.

The initial sample and population estimates for each weighting race-ethnicity group are tested against a set of criteria that require a minimum of 10 sample people and a ratio of the population control to the initial sample estimate that is between 1/3.5 and 3.5. This is done to reduce the effect of large weights on the variance of the estimates. If there are weighting race-ethnicity groups that do not satisfy these requirements, they are collapsed until all groups satisfy the collapsing criteria. Collapsing decisions are made following a specified order in the following way.

1. If the requirements are not met for Hispanics, then Hispanics are collapsed with the largest non-Hispanic non-White group.
2. If the requirements are not met for any non-Hispanic non-White group, it is collapsed with the largest (prior to collapsing) non-Hispanic non-White group.
3. If the largest collapsed non-Hispanic non-White group still does not meet the requirements, it is collapsed with the surviving non-Hispanic non-White groups in the following order until the requirements are met: Black, American Indian and Alaskan Native, Asian, and Native Hawaiian or Pacific Islander.
4. If all non-Hispanic non-White groups have been collapsed together the collapsed group still does not meet the requirements, it is collapsed with the non-Hispanic White group.
5. If the requirements are not met for the non-Hispanic White group, then it is collapsed with the largest non-Hispanic non-White group.
6. If the requirements are not met when all non-Hispanic race groups are combined then all weighting race-ethnicity groups are collapsed together and the collapsing is complete.

Within each collapsed weighting race-ethnicity group, the persons are placed in sex-age cells formed by crossing sex by the following 13 age categories: 0-4, 5–14, 15–17, 18–19, 20–24, 25–29, 30–34, 35–44, 45–49, 50–54, 55–64, 65–74, and 75+ years. If necessary, these cells also are collapsed to meet the requirements of the same sample size and a ratio between (1/3.5) and 3.5. The goals of the collapsing scheme are to keep children age 0–17 together whenever possible by first collapsing across sex within the first three age categories. In addition, the collapsing rules keep men age 18–54, women age 18–54, and seniors 55+ in separate groups by collapsing across age.

The initial sample cell estimates are then scaled and rescaled via iterative proportional fitting, or raking, so that the sum in each row or column consecutively agrees with the row or column household estimate (Steps 1 & 2) or population estimate (Step 3). This procedure is iterated a fixed number of times, and final person weights are assigned by applying an adjustment factor to the initial weights.

The scaling and rescaling between rows and columns is referred to as an iteration of raking. An iteration of raking consists of the following three steps. (The weighting matrix is included to facilitate the discussion below.) The three-step process has been split out into two tables, Table 11-5 and Table 11-6, for clarity.

Table 11-5. Steps 1 and 2 of the Weighting Matrix

Step 2: Cell	Step 1 Cell: Subcounty Area #1	…	Step 1 Cell: Subcounty Area #N	Step 2: Control
Householder in two-partner relationship				Survey estimate of married-couple and unmarried- partner households
Spouse / unmarried partner in two-partner relationship				Survey estimate of married-couple and unmarried- partner households
Householder not in two-partner relationship				Survey estimate of all single-headed households
Balance of population				Derived total household population estimate minus the sum of the other three controls
Step 1: Control	Derived household population estimate for Subcounty Area #1	…	Derived household population estimate for Subcounty Area #N	Derived total household population estimate for weighting area

Step 1. At this step, the initial person weights are adjusted to make the sum of the weights of all household persons equal to the derived household population controls for the defined subcounty control area.

Step 2. The Step 1 adjusted person weights are adjusted to make both the sum of the weights of householders in married-couple or unmarried-partner households and the sum of the weights of their spouses or unmarried partners equal to the survey estimate of married-couple and unmarried-partner households. In addition, the weights are adjusted so that the sum of the weights of householders not in a two-partner relationship equal to the survey estimate of other single-headed households. For both of these constraints, the survey estimate is calculated using the HU weight after the HU post-stratification factor adjustment. Lastly, the weights of all other persons are adjusted to make the sum of all person weights equal to the derived household population estimates.

Step 3. The Step 2 adjusted person weights are adjusted a third time by the ratio of the population estimates of race-Hispanic origin/age/sex groups to the sum of the Step 2 weights for sample people in each of the demographic groups described previously.

The three steps of ratio adjustment are repeated in the order given above until the predefined stopping criterion is met. The stopping criterion is a function of the difference between Step 2 constraints and their corresponding marginals calculated using the Step 3 weights. Internal research has shown that Step 1 converges quickly and that the driver for convergence of the weights being within tolerance of the constraints for each dimension is Step 2 (they will be equal for Step 3 since that is the last step). The raking for a weighting area is stopped when each of the marginals for Step 2 is within 0.01% of the constraint if fewer than 20 iterations have been run. If the weighting area has not converged prior to 20 iterations, the stopping criterion is relaxed to 0.1% and the raking continues. If the threshold continues to not converge, a maximum iteration limit of 40 is enforced. Approximately 95% of the weighting areas converge within 20 or fewer iterations. The weights obtained from Step 3 of the final iteration are the final person weights, *WPPSF* (the weight after the person post-stratification).

For review (and historical comparison) purposes, we define the person post-stratification factor (*PPSF*) as the net adjustment which that results from the entire ratio-raking estimation process. It is calculated as follows:

$$PPSF_i = \text{final person weight after raking} \div \text{initial person weight}$$

$$= \frac{WPPSF_i}{WHPF_i}$$

The factor is calculated and applied to each person, so that their weights become the product of their initial weights and the factor.

Table 11-6. Steps 2 and 3 of the Weighting Matrix

Step 3: Cells	Step 2 Cell: Householder in two-partner relationship	Step 2 Cell: Spouse / unmarried partner in two-partner relationship	Step 2 Cell: Householder not in two-partner relationship	Step 2 Cell: Balance of population	Step 3: Controls
Non-Hispanic White by 26 age-sex cells					Derived household population estimate for demographic cell
Non-Hispanic Black by 26 age-sex cells					…
Non-Hispanic AIAN by 26 age-sex cells					…
Non-Hispanic Asian by 26 age-sex cells					…
Non-Hispanic NHPI by 26 age-sex cells					…
Hispanic by 26 age-sex cells					Derived household population estimate for demographic cell
Step 2: Controls	Survey estimate of married-couple and unmarried-partner households	Survey estimate of married-couple and unmarried-partner households	Survey estimate of all single-headed households	Derived population estimate minus the sum of the other three controls	Derived total household population estimate for weighting area

Calculation of Final Housing Unit Factors

Prior to the calculation of person weights, each HU has a single weight which is independent of the characteristics of the persons residing in the HU. After the calculation of person weights, a new HU weight is computed that takes into account the characteristics of the householder in the HU. In each interviewed occupied HU, the householder is identified as one of the persons who rents or owns the HU. Adjustment of the HU weight to account for the householder characteristics is done by assigning a householder factor (*HHF*) for an HU equal to the person post-stratification factor (*PPSF*) of the householder. Their *PPSF*s give an indication of relative coverage for households whose householders have the same demographic characteristics. The

HHF adjustment uses this information to adjust for the resultant bias. Note that because the total weight for occupied units was constrained in the person raking methodology, this adjustment impacts the distribution of the weight of the housing unit weights to reflect the relative coverage rates of different householders but it generally does not perform any further adjustments for overall coverage. The adjustment for overall coverage for all housing units was addressed in the HPF adjustment. Vacant HUs are given an HHF of 1.0 because they have no householders.

The adjusted HU weight accounting for householder characteristics is computed as a multiplication of the adjusted HU weight after the HU post-stratification factor adjustment *(WHPF)* with the householder factor (HHF). Therefore, $WHHF = WHPF \times HHF$, where $WHHF$ is the adjusted HU weight after the householder factor adjustment. The HU weight after the householder factor adjustment becomes the final HU weight.

The ACS weighting procedure results in two separate sets of weights: one for HUs and one for persons residing within HUs. However, since the housing unit weight is equal to the person weight of the householder, the survey produces logically consistent estimates of occupied housing units, households, and householders. With this weighting procedure, the survey estimate of total HUs differs slightly from the PEP total housing unit estimates but is typically within a tenth of a percent at the county level.

11.11 Multiyear Estimation Methodology

The multiyear estimation methodology involves reweighting the data for each sample address in the 5-year period and is not just a simple average of the one-year estimates. The weighting methodology for the multiyear estimation is very similar to the methodology used for the single-year weighting. Thus, only the differences between the single- and multiyear weighting are described in this section.

Pooling the Data

The data for all sample addresses over the multiyear period are pooled together into one file. The single-year base weights are then adjusted by the reciprocal of the number of years in the period so that each year contributes its proportional share to the multiyear estimates. For the 5-year weighting, the base weights are thus all divided by five.

The interview month assigned to each address is also recoded so that all the data from the entire period appears as though it came from a one-year period. For example, in the 2012–2016 5-year weighting, all addresses that were originally assigned an interview month of January 2012, 2013, 2014, 2015, or 2016 are assigned the common interview month of January. Thus, when the weighting is performed, those records all are treated as though they come from the same month for the *VMS* adjustment. This should better preserve the seasonal trends that may be present in the population as captured by the ACS.

Geography

The geography for all sample addresses in the period is updated into the common geography of the final year. This allows the tabulation of the data to be in a consistent, constant geography that is the most recent and likely most relevant to data users. When tabulating estimates for an area, all interviews from the period that are considered to be inside the boundaries of that area in the final year of the period are included in the estimates regardless of if they were considered to be inside the boundaries for that area at the time of interview. As a by-product of this methodology, the ACS is also able to publish multiyear estimates for newly created places or counties that did not exist when the interviews for the addresses in that place or county were collected.

Derivation of the Multiyear Controls

Since the multiyear estimate is an estimate for the period, the controls are not those of a particular year but rather they are the average of the annual independent population estimates over the period. The Population Estimates Program refreshes their entire time series of estimates going back to the previous census each year using the most current data and methodology. Each of these time series are considered a “vintage”. To make use of the best available population estimates as controls, the ACS multiyear weighting uses the population estimates of the most recent vintage for all years in the period in order to derive the multiyear controls.

These derived estimates are created for the housing unit, group quarters population, and total population for use as controls in the multiyear weighting. The derived county-level housing unit estimates are the simple average across all years in the period. Since the average is typically not an integer, the result is rounded to form the final estimate. Likewise, the derived group quarters population estimates for state by major type group are the simple average across all years in the period. Those averages are then control rounded so that the rounded state average estimate is within 1 of the unrounded estimate. Finally, the derived total population estimates by race, ethnicity, age and sex are averaged across all years in the period and control rounded to form the final derived estimates. This is done prior to the collapsing of the estimates into the 156 cells per weighting area needed for the demographic dimension of the household person weighting as described in the single-year person weighting section.

The weighting areas used for the multiyear estimation are generally smaller than those used for the single-year estimation. They are still formed by complete counties or aggregations of counties and they must meet a threshold of 400 unweighted person interviews at the time of their formation. In addition, for the five-year estimation, the weighting area must have a minimum population of 2,500.

However, since there is no publication threshold for the five-year data product, there are counties which are not their own weighting area and therefore greater differences between the ACS and PEP estimates of total population may exist particularly for counties smaller than 2,500 in total population. For the formation of the subcounty control areas, the single-year threshold of 24,000 in total population is reduced for the five-year weighting to 2,500.

Model-assisted Estimation

Once the data are pooled and put into the geography of the final year, they are weighted using the single-year weighting methodology through the *NIF* adjustment. It is after this adjustment that the only multiyear-specific weighting step is implemented, the model-assisted estimation procedure. An earlier research project (Starsinic, 2005) compared the variances of ACS tract-level estimates formed from the 1999–2001 ACS to the variances of the Census 2000 long-form estimates. The results of that research showed that the variances of the ACS tract-level estimates were higher in relation to the long form than was expected based on sample size alone. The primary source of that increased variance was attributed to the lack of ACS subcounty controls at the tract-level or lower as was used for the long form.

Several options were explored on how the ACS might improve our estimates of variance for subcounty estimates. One option considered was to use the ACS sampling frame counts as subcounty controls. Other options explored ways to create subcounty population controls, including tract-level population controls. The final approach that was chosen introduces a model-assisted estimation step into the multiyear weighting that makes use of both the sampling frame counts and administrative records to reduce the level of variance in the subcounty estimates (Fay, 2006). An important feature of the model-assisted estimation procedure is that the administrative record data are not used directly to produce ACS estimates. The administrative record data are only used to help reduce the level of variance. This is an important property of this step as the coverage for administrative records for small areas such as tracts can vary significantly year-to-year. Had we pursued using the administrative record directly to impact the estimates, this variability in coverage could have led to unpredictable impacts on the quality of the ACS data. By using the administrative record data for variance reduction only, the impact of this coverage on the ACS is principally on the degree of variance reduction that is achieved and not on the directly on estimates themselves. The published ACS estimates are still formed from weighted totals of the ACS survey data.

The model-assisted estimation step is calculated at the at the tract level for the ACS 5-year data. The entire model-assisted estimation process is summarized in these steps.

1. Create frame counts for tracts that contain at least 300 housing unit addresses.
2. Link the administrative records to the ACS sampling frame (the Master Address File or MAF) dropping administrative records that cannot be linked.
3. Form unweighted geographic totals of the linked administrative record characteristics.
4. Apply the *WNIF* weights at the housing-unit level to the linked administrative records that fall into the ACS sample. The weighted estimates at this step represent (essentially) unbiased estimates of the unweighted totals in Step 3.
5. Using generalized regression estimation, fit a model to calibrate the ACS weights so that the weighted totals from the linked ACS records match the unweighted totals from Step 3 and so that the weighted ACS estimate of HUs match the frame totals in Step 1. The categories of the variables considered in

the regression are collapsed or removed as necessary to fit a good model.

6. Proceed with the remaining steps of the ACS weighting starting with the *HPF* adjustments, including the person weighting using the derived multiyear controls as described in the preceding section.

Frame Counts: The base weights (*BW*), which reflect the sampling probabilities of selection, should sum to the count of records on the sampling frame at the county and, generally, the subcounty level. However, after the weighting steps that follow the base weight assignment through the noninterview adjustment, the weighted subcounty distribution of the interviewed sample cases can deviate from the original frame distribution. This can impact both the subcounty estimates and the variances on those estimates. The use of the frame counts reestablishes the original subcounty distribution of housing unit addresses on the frame in the weighted sample. This control to the frame counts is the simplest model and is used if a model with administrative record data cannot be estimated. Otherwise, it is one part of the entire calibration performed in this step.

Link Administrative Records to Frame: The administrative record data used for this step is created from linking two primary files maintained by the Economic Reimbursable Division at the Census Bureau. The first file includes person characteristics and has been created from a combination of Social Security and census information. The second file uses administrative records to identify all possible addresses of the persons on the first file. A merged file is then created which contains only the age, sex, race, and Hispanic origin of each person and an identifier that links that person to the best address available in the MAF via a Master Address File ID (MAFID). No other characteristics or publicly identifiable information are present on the file. This file is updated annually to account for new births, death information, and for updated address information.

Administrative Universe Counts: For each MAFID, it is possible to create household demographic totals of people by age/sex and race/ethnicity from the merged administrative records for each address that is matched to the MAF. The age/sex totals are calculated within seven categories:

1. All persons age 0–17
2. All persons age 18–29
3. Males age 30–44
4. Females age 30–44
5. Males age 45–64
6. Females age 45–64
7. All persons age 65 and older

The race/ethnicity totals are calculated within four categories:

1. All Hispanics regardless of race
2. All non-Hispanic blacks

3. All non-Hispanic whites
4. All non-Hispanics other races

These household-level totals can then be used to create unweighted tract-, place- and MCD-level administrative record universe totals using the geography associated with the address.

Weighted Administrative Sample Counts: The administrative records that match to the sampling frame can also be linked to the actual ACS sample records themselves. Using the *WNIF* weights, the records that match to the ACS sample can then be used to create weighted administrative record totals for the same geographic areas. Since the ACS sample weights should reflect the frame counts, these weighted administrative record totals should be an unbiased estimate of the unweighted matched universe totals.

Applying GREG Estimation: Using generalized regression estimation (or GREG), the ACS weights are first calibrated so that the weighted administrative record totals match the unweighted universe counts for the seven age/sex categories. Two conditions are checked: is the regression equation solvable and are all of the resulting weights greater than 0.5. If either condition fails, then the age/sex categories are collapsed and the regression is attempted again.

Two levels of collapsing are attempted:

1. Collapsing across age/sex categories into three categories: all persons age 0–17, all persons age 18–44 and all persons 45 and older.
2. Collapse all categories into a single cell of total administrative persons.

If the condition still fails after the second level of collapsing, then the administrative record data are not used.

If the regression passes using at least the single cell of total administrative persons, then an attempt is made to add the race/ethnicity covariates to the model. First, a collapsing procedure is run that tests which race/ethnicity categories can be used. The criteria for including a race/ethnicity category in the regression is that both the administrative records universe count for the category being tested and the total for all other categories must be greater than 300 persons. This procedure is carried out first for the largest race/ethnicity category not including the non-Hispanic white category, then the next largest such category, and finally the last remaining category other than non-Hispanic white.

As an example, if the largest category other than non-Hispanic white was the Hispanic category, then the first test would be if 1) the Hispanic category had a universe count which was greater than 300 and 2) the other three categories combined had a universe count greater than 300. If it passes, the Hispanic category is flagged for inclusion and the remaining categories are tested. If the next largest category is non-Hispanic black, it is tested to determine if its universe count is greater than 300 and if the balance, now only the non-Hispanic other races and non-Hispanic white, is greater than 300. If it passes, then the procedure moves on to test the smallest category other than non-Hispanic white. In this example, that is the non-Hispanic other race category. If a similar test on that category fails (or on any previous attempt) then the race collapsing is complete and the covariates for each race/ethnicity category that passed are added to the model. The regression is then attempted including both the age/sex and race/ethnicity covariates. The same conditions used in the age/sex category collapsing are applied to the new attempt. If the regression passes both conditions, then the covariate matrix is considered final. If the regression fails either condition, then the smallest race/ethnicity category is not included in the model and the regression is attempted again. This process continues until either the regression passes or all race/ethnicity covariates have been removed. The final result of this step is the creation of the GREG Weighting Factor (*GWTF*) for each ACS record, which captures the calibration performed in the regression. A summary of the impact of the GWTF is given in Table 11-7.

Table 11-7. Impact of GREG Weighting Factor Adjustment

Interview Status	Frame and Model Criteria Status	ACS Record Matches to Administrative Data	Impact of *GWTF*
Noninterview or non-responding HU not sampled for CAPI	Not applicable	Not applicable	No impact (factor set to 1)
Interview or field-determined ineligible HU	Tract fails both frame count and model criteria	Not applicable	No impact (factor set to 1)
Interview or field-determined ineligible HU	Tract passes the frame count criterion but fails model criteria	Not applicable	Calibrates weights to frame counts for the tract
Interview or field-determined ineligible HU	Tract passes both the frame count and model criteria	Does not match	Calibrates weights to frame counts for the tract
Interview or field-determined ineligible HU	Tract passes both the frame count and model criteria	Does match	Calibrates weights to frame counts for the tract and Calibrates weighted admin data to admin universe counts for tract

This factor is then applied to the WNIF weights to create the Weight after the GREG Weighting Factor (*WGWTF*). The computation of this weight is summarized in Table 11-8.

Table 11-8. Computation of the Weight After the GREG Weighting Factor ($WGWTF$)

Interview Status	$WGWTF_j$
Interview or field-determined ineligible housing unit	$WNIF_j \times GWTF_j$
All others	0

After this step is complete, the multiyear weighting mirrors the single-year weighting, picking up again at the *HPF* step.

Other Multiyear Estimation Steps

In addition to the adjustments to the single-year weighting methodology for weighting the multiyear data, there are other steps involved in the multiyear estimation that are not weighting related. These include standardizing definitions of variables, updating the geography for place of work and migration characteristics, and the adjustment of income, value and other dollar amounts for inflation over the period. The details of these adjustments are given in Chapter 10.

11.12 References

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Chapter 11 Revision History

Author	Date	Brief Description of Change	Version #
C. Rosol	1/30/2014	Final draft (2014 edition) to be published	2.0
M. Asiala & E. Castro	11/28/2022	Content and formatting edits. Approval of Final Edits	3.0